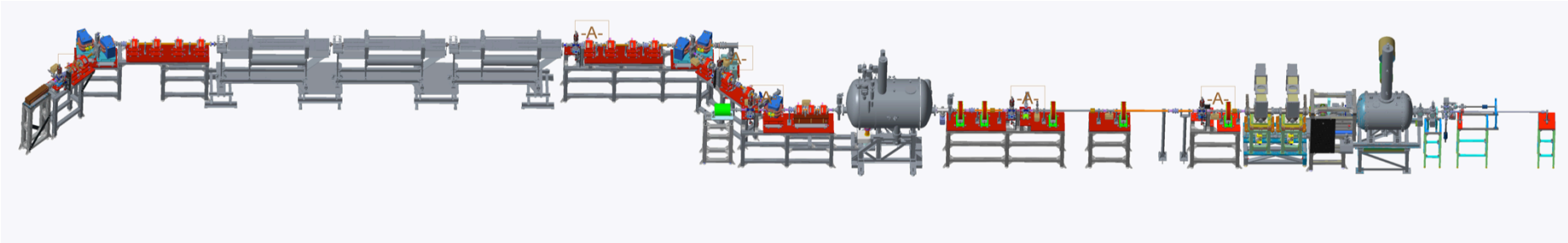
Coherent electron Cooling (CeC) PoP experiment

Vladimir N. Litvinenko - PI
Igor Pinayev – Project physicist
Joseph Tuozzolo – Project Engineer
for CeC team

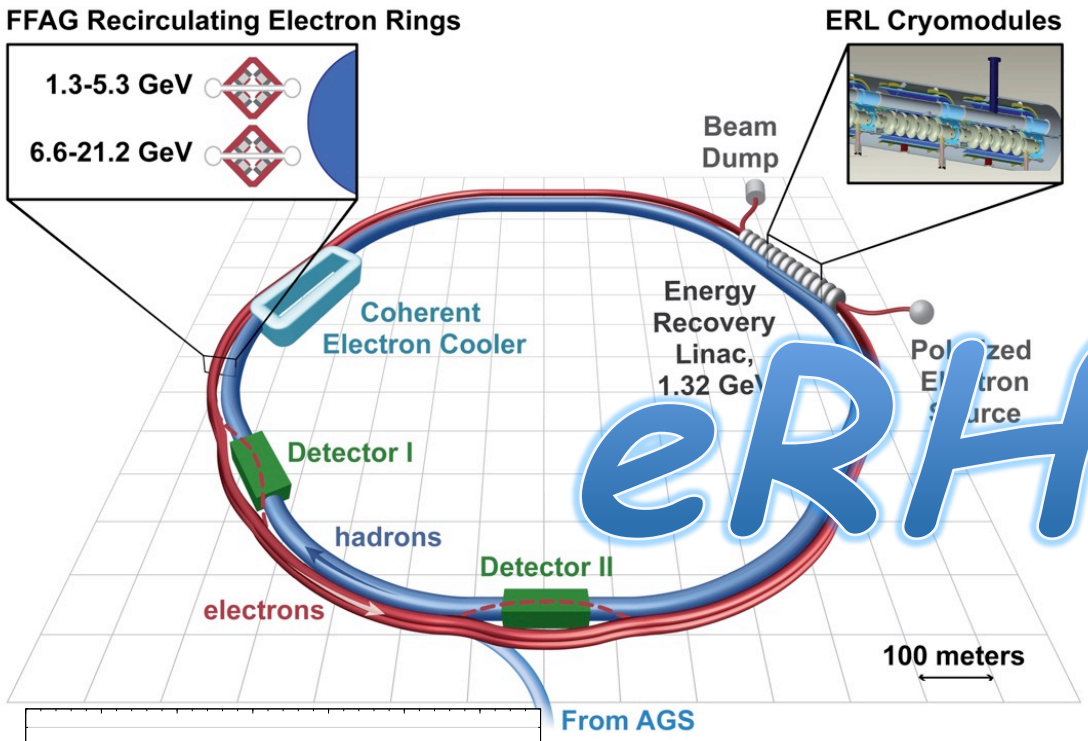
C-AD, Brookhaven National Laboratory, Upton, NY, USA
Stony Brook University, Stony Brook, NY, USA
Niowave Inc., Lansing, MI, USA, Tech X, Boulder, CO, USA
Budker Institute of Nuclear Physics, Novosibirsk, Russia
STFC, Daresbury Lab, Daresbury, Warrington, Cheshire, UK



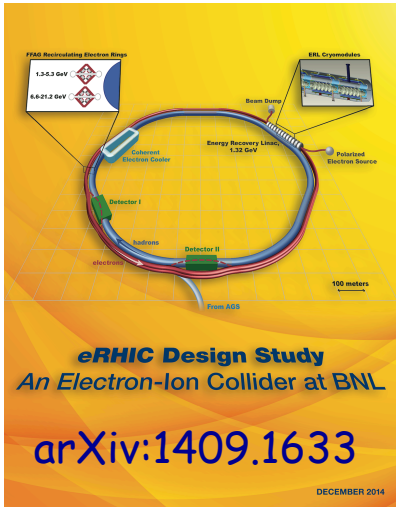
ARR March 1, 2016

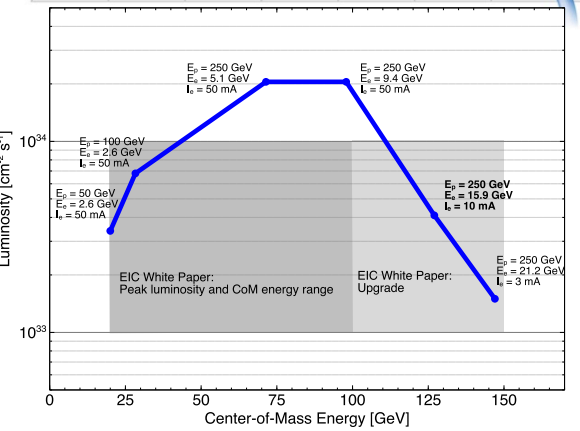
Welcome

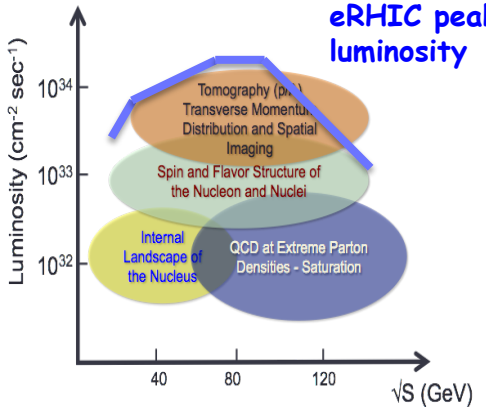
Why we doing this?

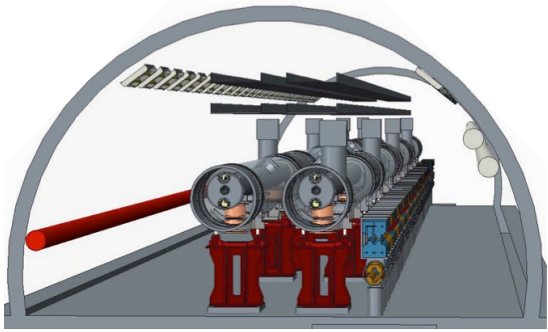


eRHIC





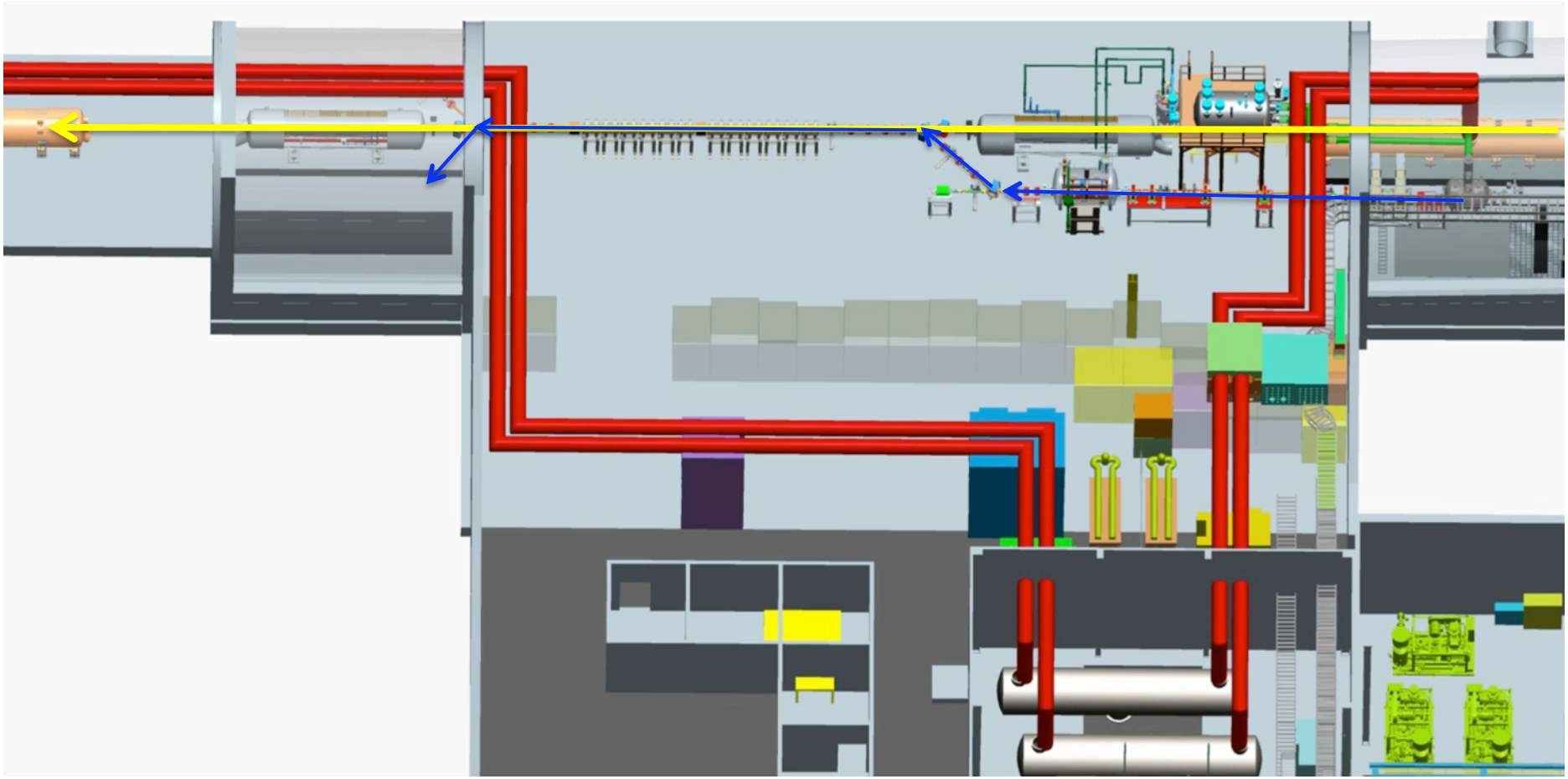




Coherent electron Cooling is needed and has to be tested -> CeC PoP

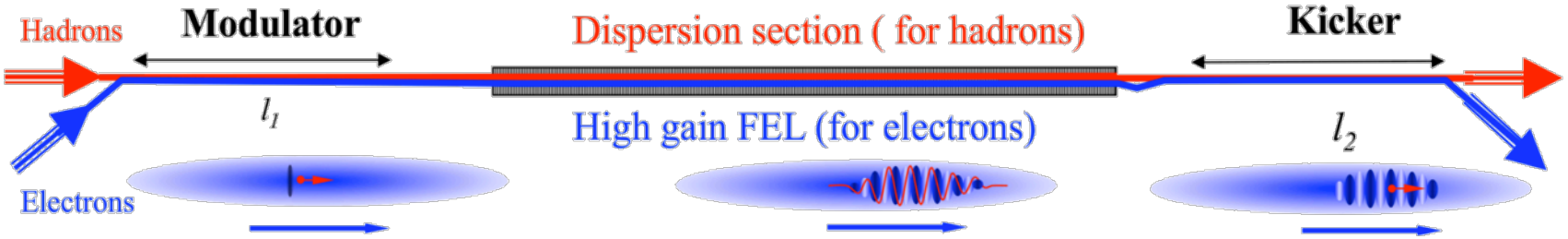
CeC PoP: Readiness and Look Ahead

CeC Proof-of-Principle Experiment

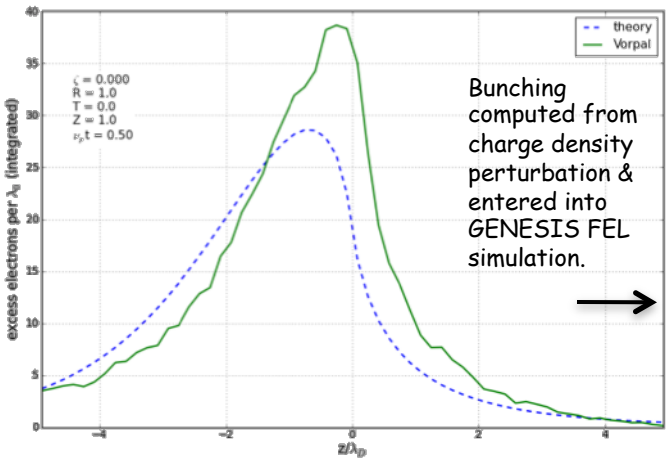


Coherent electron *Cooling* PoP

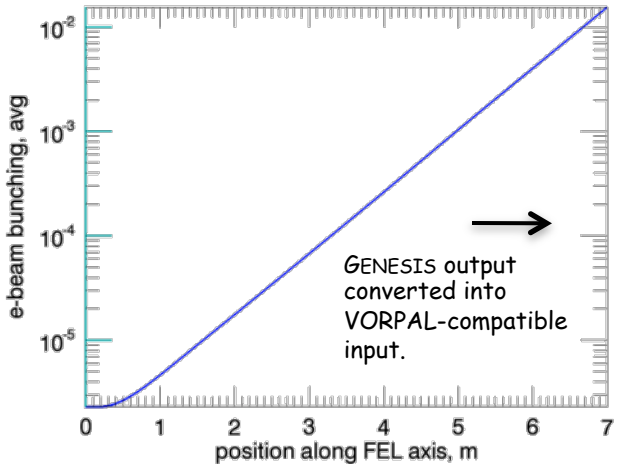
Our Proof-of-Principle is an economic version of CeC where electrons and hadrons are co-propagate along the entire CeC system



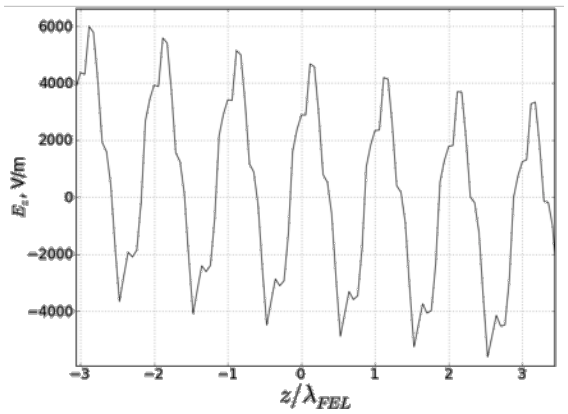
Param.' s from 40 GeV proof-of-principle exp. at BNL



VORPAL 3D δf PIC computation of e- density perturbation near Au^{+79} ion (green) vs. idealized theory (blue). On Cray XE6 cluster at NERSC.



GENESIS parallel computation of electron beam bunching in free electron laser (FEL) shows amplification of modulator signal.

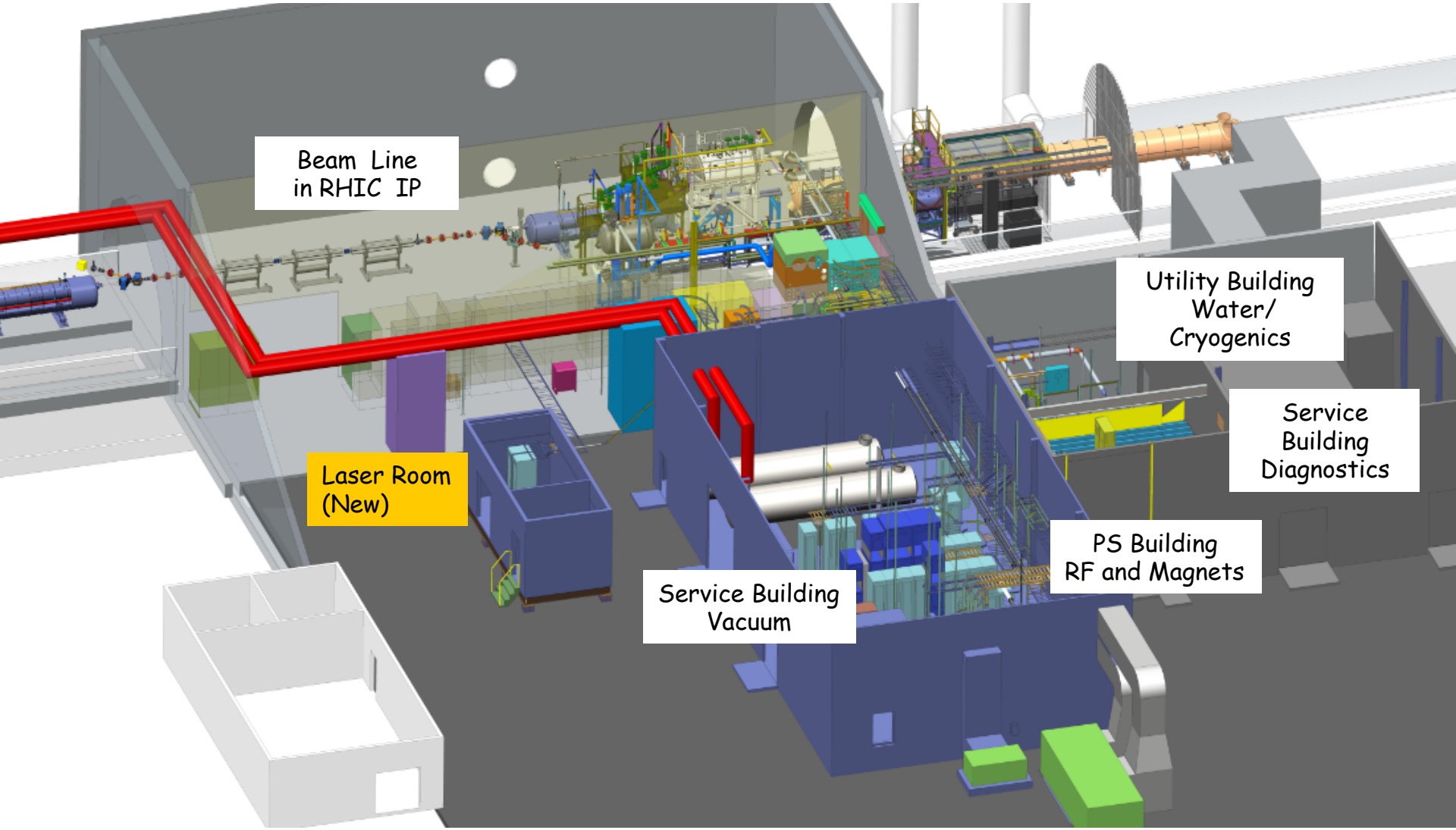


VORPAL prediction of the coherent kicker electric field E_k due to e-density perturbation from modulator, amplified in the FEL.

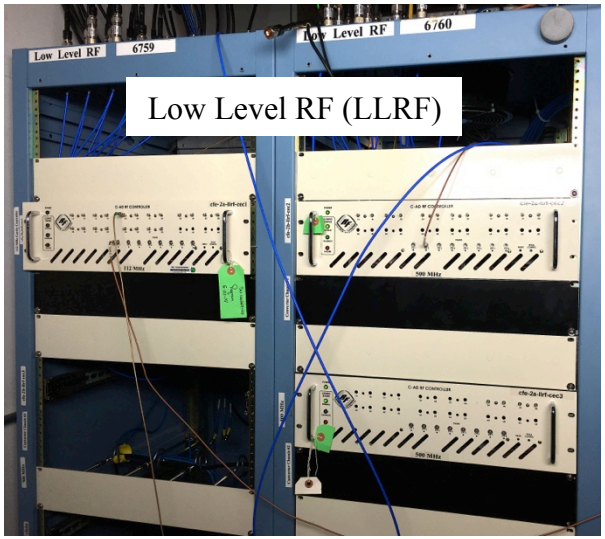
Simulations by Tech-X

Office of Nuclear Physics
Exploring Nuclear Matter - Quarks to Stars

CeC PoP 3D rendering

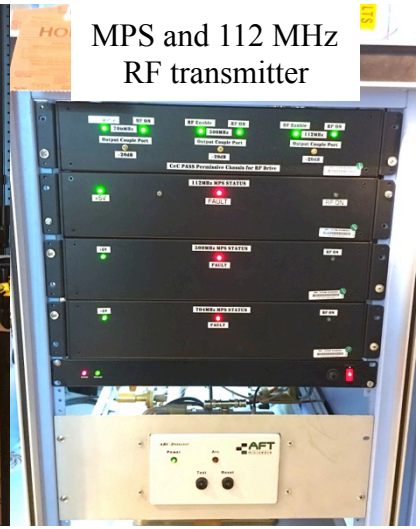


Some of CeC electronics

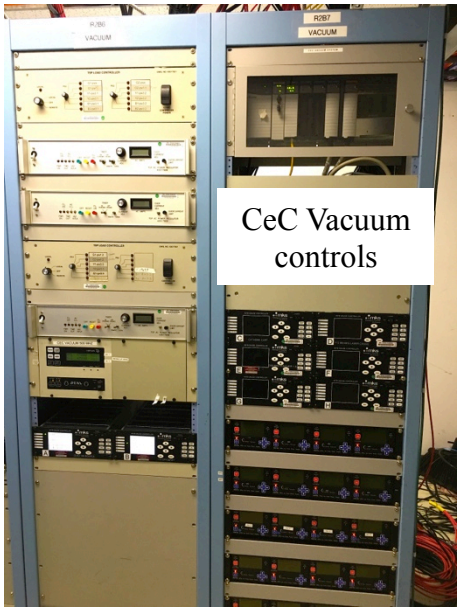


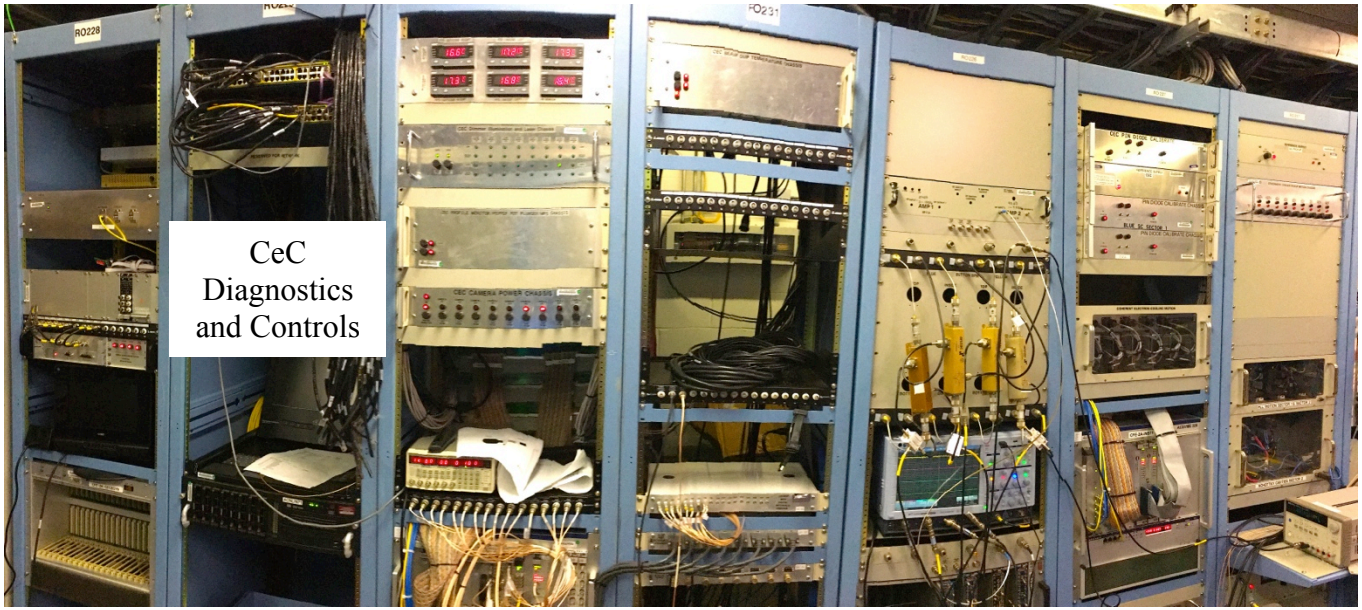
Low Level RF (LLRF)

500 MHz and 704 MHz RF transmitters


MPS and 112 MHz RF transmitter


CeC magnet power supplies


CeC Vacuum controls

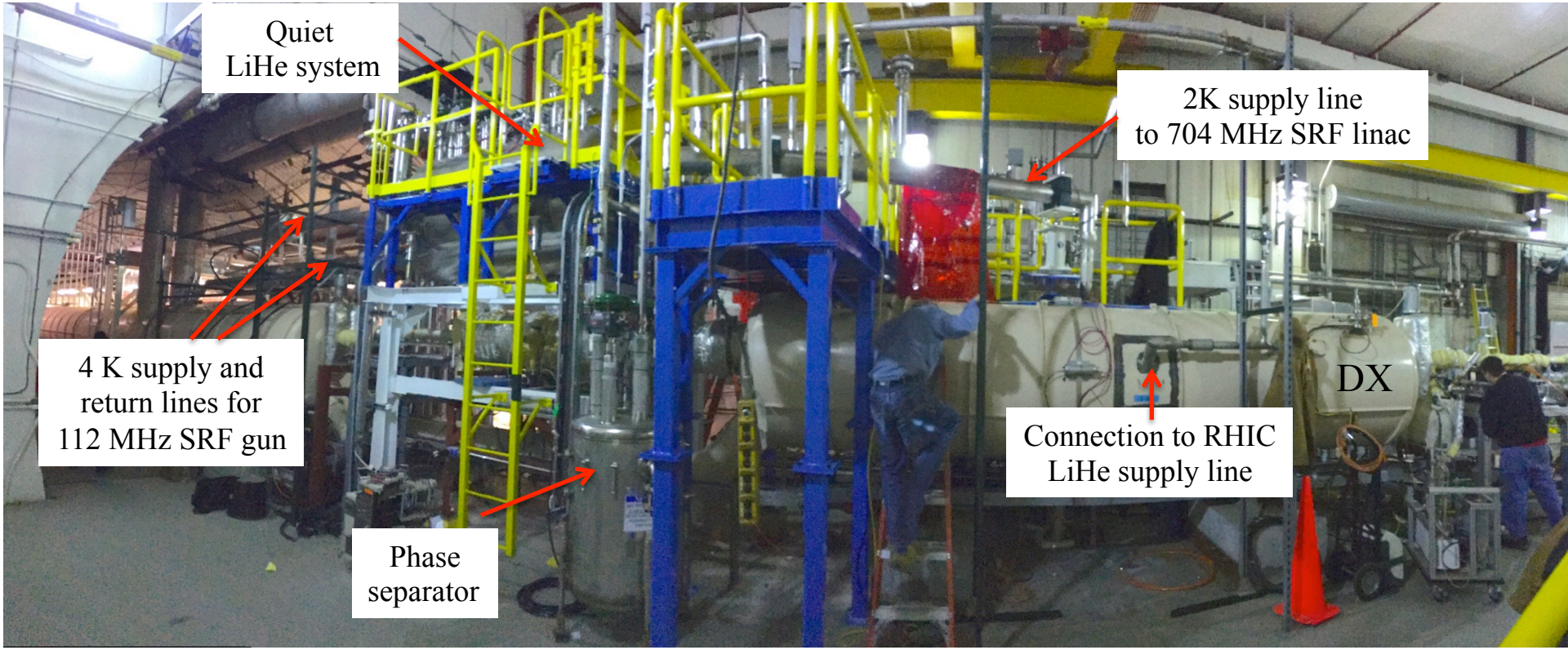


CeC Diagnostics and Controls

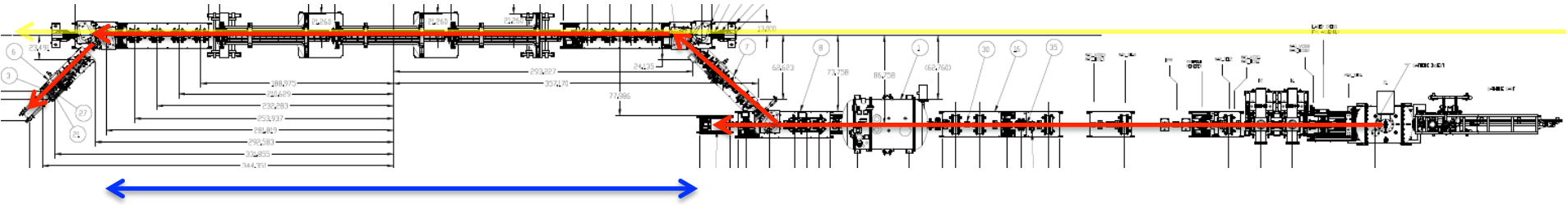
Office of Nuclear Physics
Exploring Nuclear Matter - Quarks to Stars

CeC cryo pumps and compressor, DI water

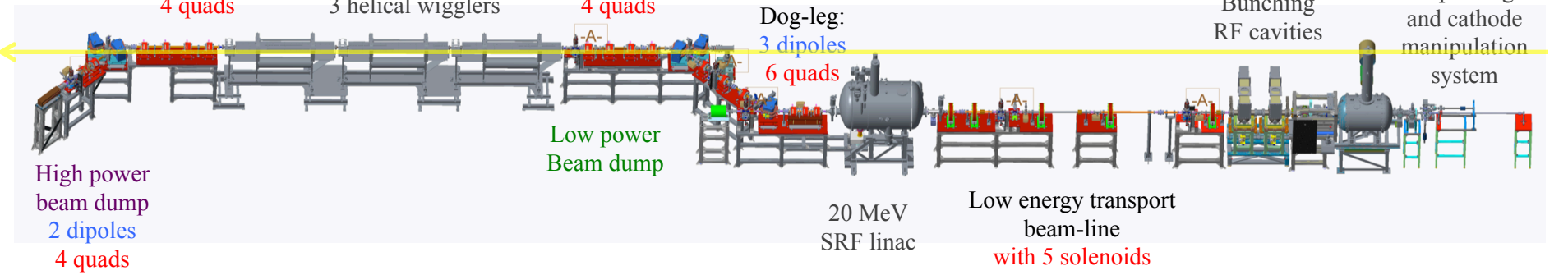
CeC cryo-system at IP2



The CeC system

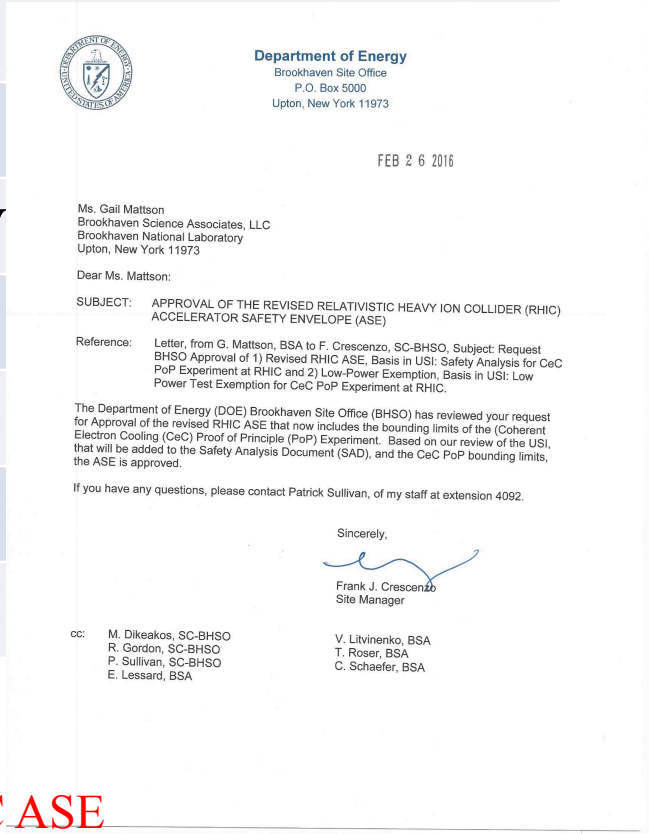


Common section with RHIC



Main Beam Parameters for CeC Experiment

Parameter	Value
Species in RHIC	Au^{+79} ions, 40 GeV/u
Relativistic factor	42.96
Number of particles in bucket	10^9
Electron energy	21.95 MeV
Charge per e-bunch	0.5-5 nC
Rep-rate	78.17 kHz
Average e-beam current	0.39 mA
Electron beam power	8.6 kW



Department of Energy
Brookhaven Site Office
P.O. Box 5000
Upton, New York 11973

FEB 2 6 2016

Ms. Gail Mattson
Brookhaven Science Associates, LLC
Brookhaven National Laboratory
Upton, New York 11973

Dear Ms. Mattson:

SUBJECT: APPROVAL OF THE REVISED RELATIVISTIC HEAVY ION COLLIDER (RHIC) ACCELERATOR SAFETY ENVELOPE (ASE)

Reference: Letter, from G. Mattson, BSA to F. Crescenzo, SC-BHSO, Subject: Request BHSO Approval of 1) Revised RHIC ASE, Basis in USI: Safety Analysis for CeC PoP Experiment at RHIC and 2) Low-Power Exemption, Basis in USI: Low Power Test Exemption for CeC PoP Experiment at RHIC.

The Department of Energy (DOE) Brookhaven Site Office (BHSO) has reviewed your request for Approval of the revised RHIC ASE that now includes the bounding limits of the (Coherent Electron Cooling (CeC) Proof of Principle (PoP) Experiment. Based on our review of the USI, that will be added to the Safety Analysis Document (SAD), and the CeC PoP bounding limits, the ASE is approved.

If you have any questions, please contact Patrick Sullivan, of my staff at extension 4092.

Sincerely,

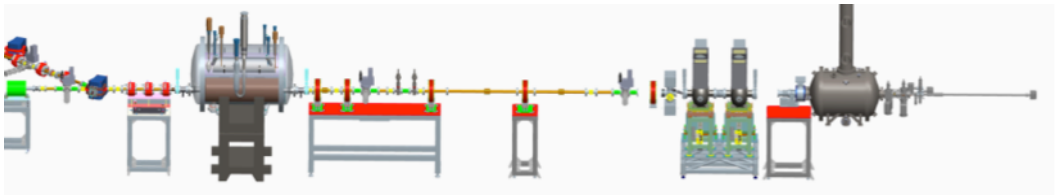
Frank J. Crescenzo
Site Manager

cc: M. Dikeakos, SC-BHSO
R. Gordon, SC-BHSO
P. Sullivan, SC-BHSO
E. Lessard, BSA
V. Litvinenko, BSA
T. Roser, BSA
C. Schaefer, BSA

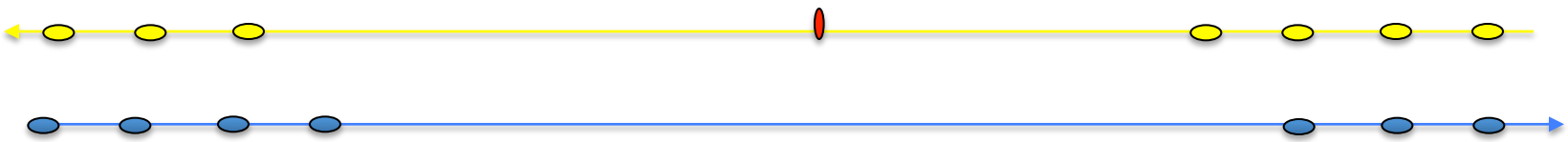
✓ CeC experiment parameters are well within revised RHIC ASE

How do we operate I

- Commissioning of CeC accelerator
  - Parallel to RHIC operation, except occasional requests for access



- Propagating electron beam through the IP2 to the dump at low rep-rate, tune FEL amplification
  - Parallel to RHIC operation: electron bunches passing through the IP2 during Blue abort gap and between 2 yellow bunches



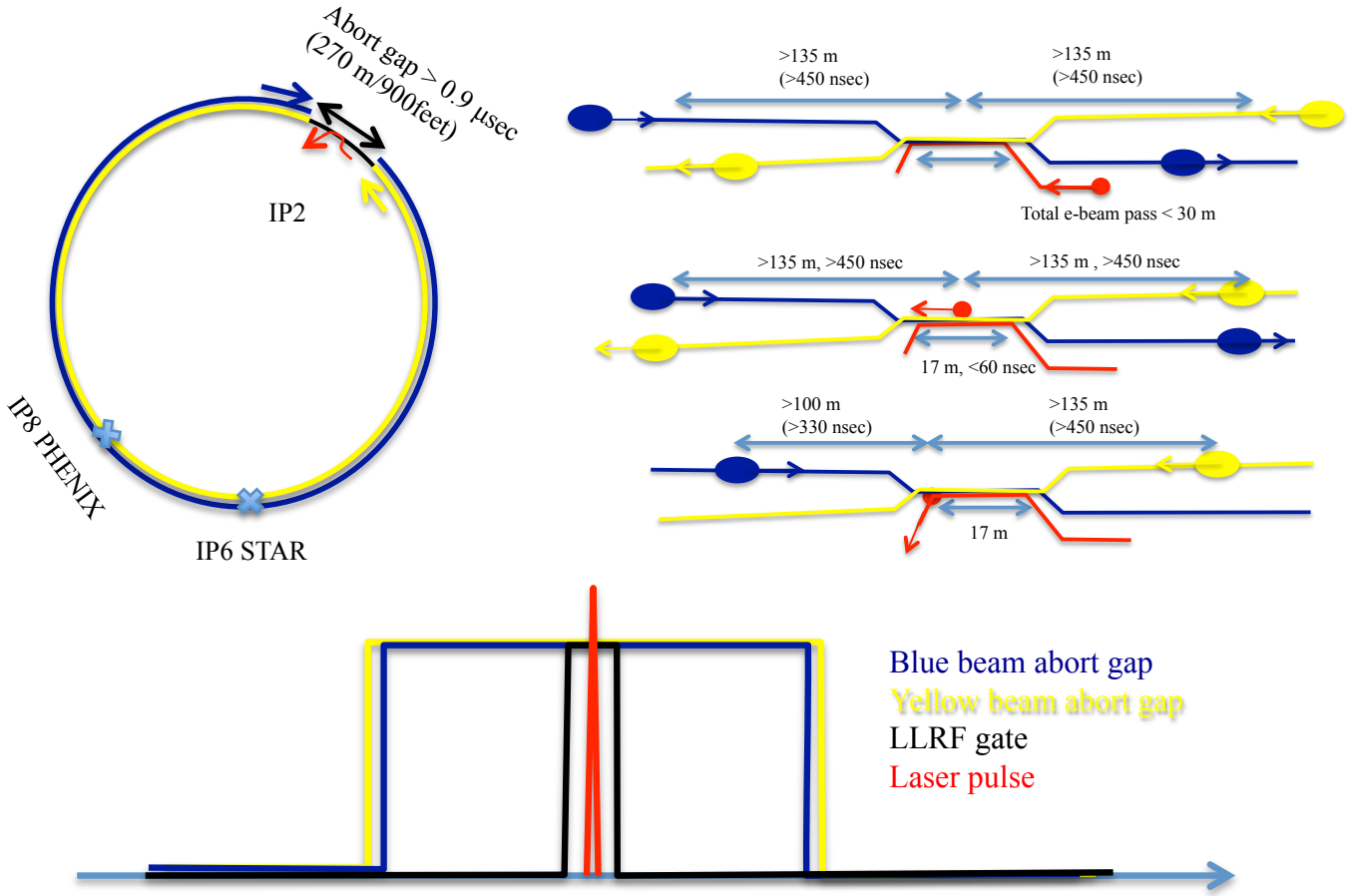
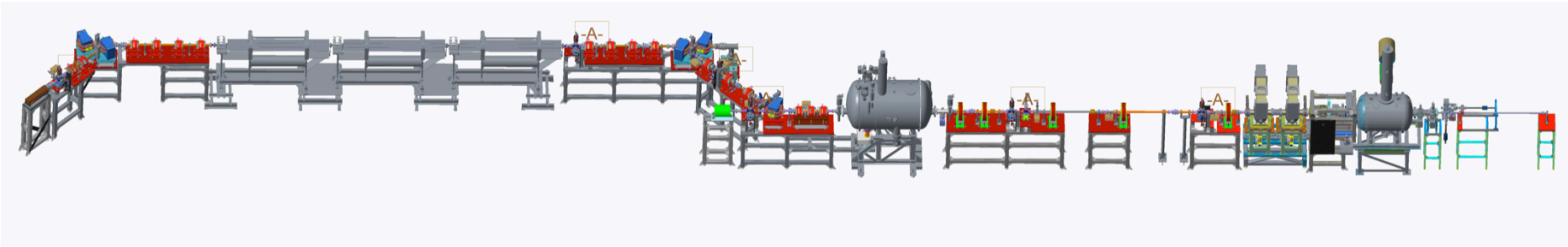


Figure 3 In RHIC, colliding hadron beams have an abort gap that is typically 1 microsecond long but always longer than 0.9 microseconds. By design, these abort gaps always overlap at IP8 and IP2. It provides a long period when there are zero hadrons in the 19-m long straight section common for yellow and blue hadron beam and CeC's electron beam. CeC Pop Experiment will use 200 nsec of this gap to propagate electron beam in the common section. The gate window for this propagation will be opened by the RHIC/CeC low-level RF system.

Installation Is Finished*

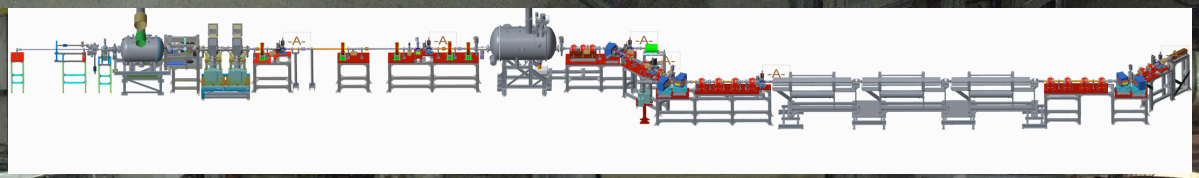
- All accelerator section and dog-leg are installed and ready for commissioning
- Magnet installation and wiring is completed
- The common section with RHIC – the Coherent electron cooling section - with 4 dipoles, 8 quadruples, 3 helical wiggles, trims and diagnostics is completed. Hadron beams are circulating through it.
- The high power dump line is in place with one element taken out for investigation* - will be reinstalled tomorrow
- Most of sub-systems needed for commissioning and operation: vacuum, water, cryo, RF, PS, diagnostics are in place and had been tested to a degree sufficient to start commissioning
- Injection (SRF gun) system was tested in July 2015 at low power

* A beam profile monitor from the beam-bump line was taken out for investigation and will be re-installed this Wednesday (March 2, 2016)



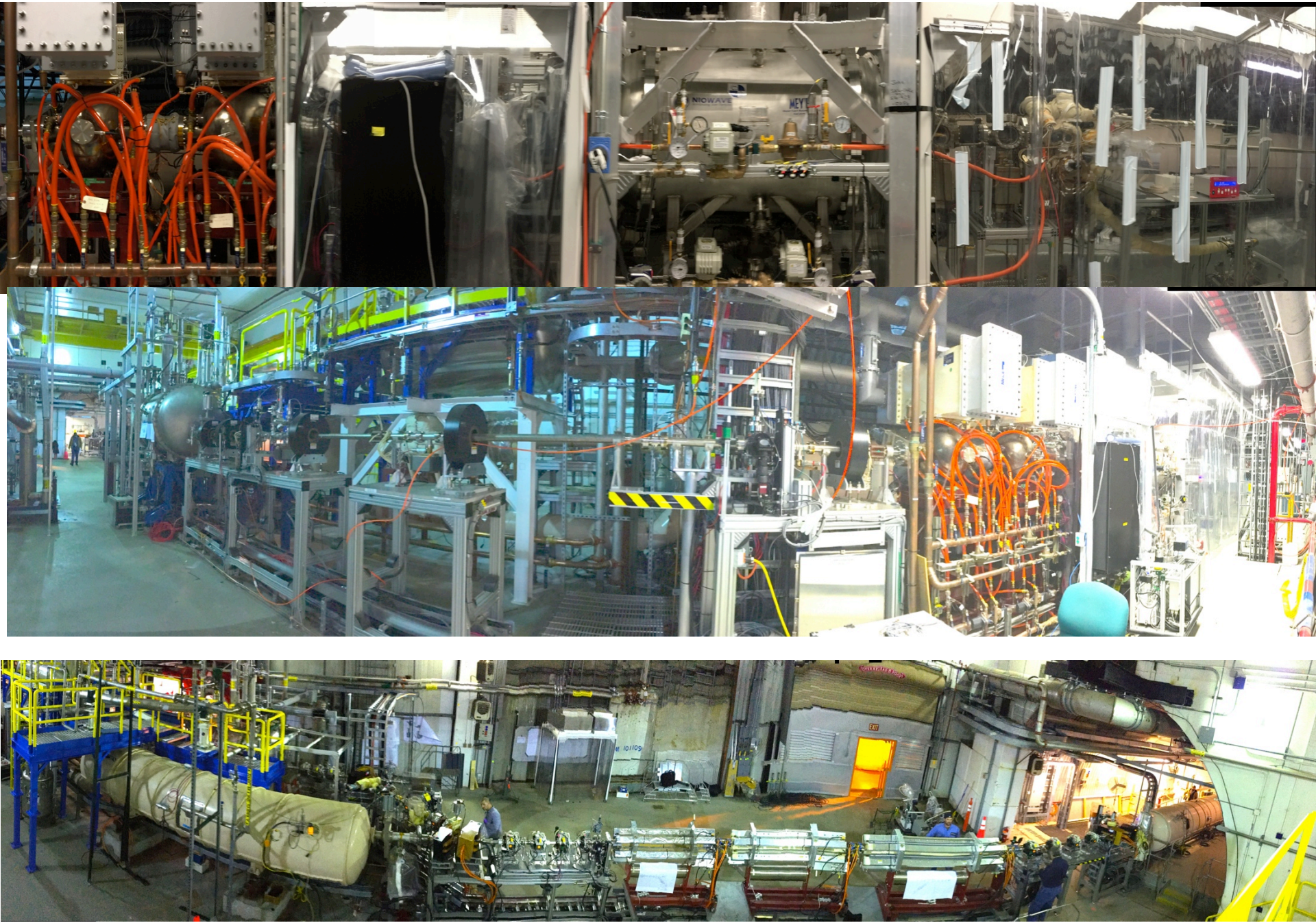
Panoramic views

From inside RHIC ring



From outside RHIC ring

Panoramic views



Show movie

Where are we at the moment?

Action Items from internal BNL reviews : **total 76**

Pre-start: 63 - total	33 – closed	30 – active
Post-start: 13 - total	4 – closed	9 - active

Main steps for CeC

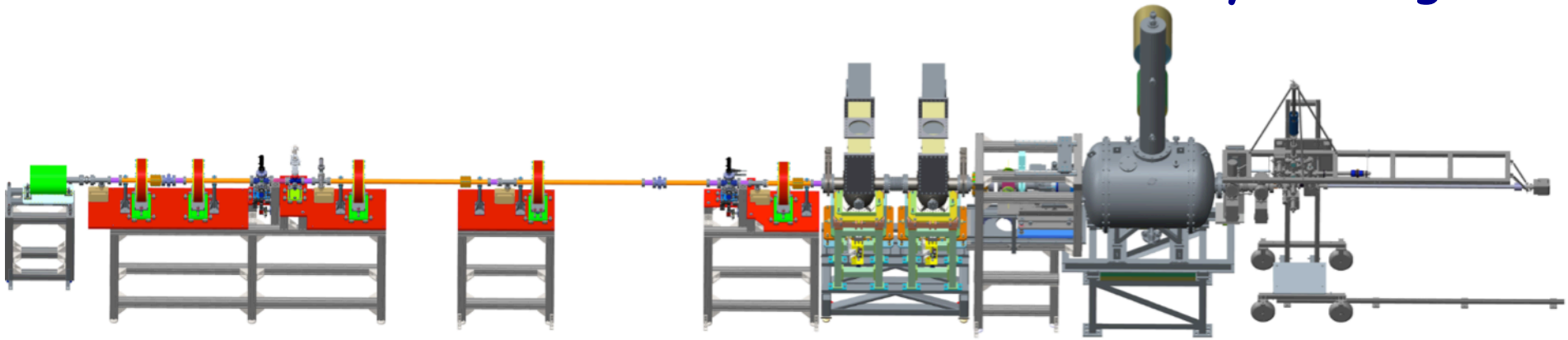
0. Finish installation of CeC PoP system into IP2
1. Developing RHIC ramp with proper beam envelope (beta*) in IP2
2. Developing RHIC ramp for CeC PoP experiment
3. CeC ARR
4. Conditioning of CeC RF system (112 MHz, 500 MHz & 704 MHz): design voltage, synchronized to RHIC beam, full control of voltage and phase
5. Re-commission the SRF gun, 500 MHz bunching cavities and accelerate beam to 20 MeV and beam power < 1W
6. Measure beam parameters (charge, emittance, peak current, energy spread…)
7. Increase beam power 10x. follow by radiation surveys (and fault studies <10 W)
8. Propagate full power 20 MeV e-beam to the beam dump, match the beam into FEL
9. Commission IR FEL diagnostics and demonstrate FEL amplification
10. **END OF FULLY PARASITIC OPERATION**
11. Co-propagate, align and synchronize electron and ion beams
12. Match relativistic factors (velocities) of hadron and electron beams
13. Observe amplification of the density modulation
14. Attempt to observe local cooling

Conclusions

- ✓ CeC proof-of-principle system is in place (last element to be re-installed tomorrow)
- ✓ We are ready to start commissioning after closing the remaining action times and receiving approval from DoE Brookhaven Area Office
- ✓ The operation/commissioning team is trained and ready for 8-hour shifts

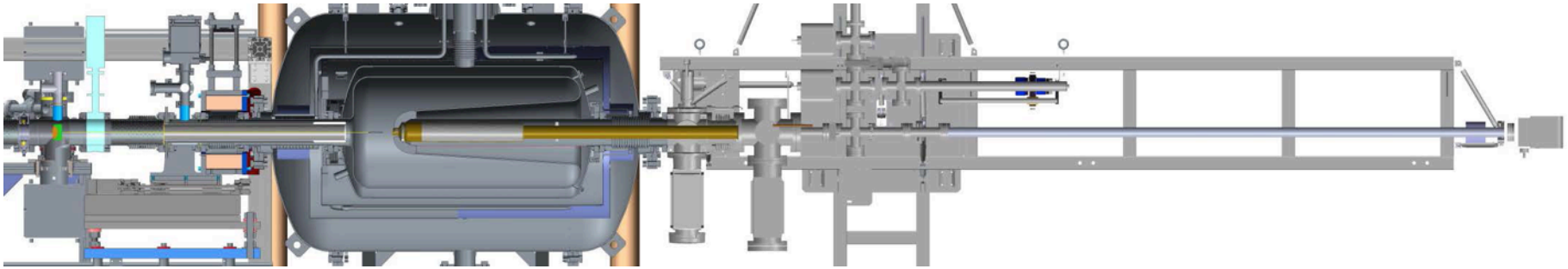
Back-up

Phase 1 – Beamline installation and 112 MHz Cavity Testing



CeC Phase 1 goals: 2014

- Install 112 MHz Cavity, Support Systems, and Cathode
- Install Beamline and Low Intensity Dump
- Make 112 MHz Cavity Cold and Test
  - (October 20)"dry run", ASSRC walk through
  - (October 27) cold test
  - (October 30) conditioning underway
  - (December 4) **2 MV !!**



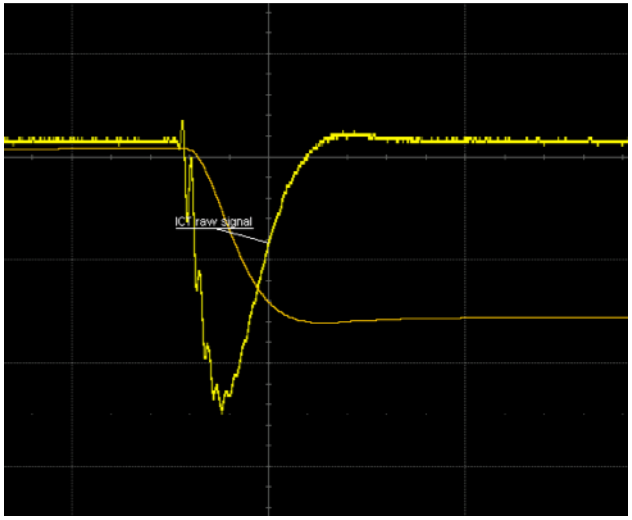
First beam from 112 MHz gun – June 2015

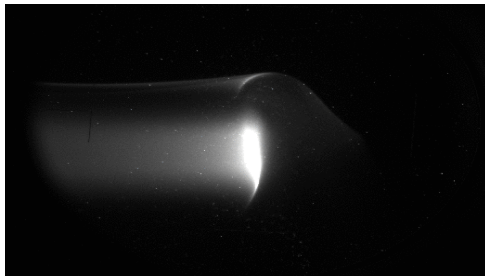
1.6-1.7 MeV (kinetic energy) in CW mode

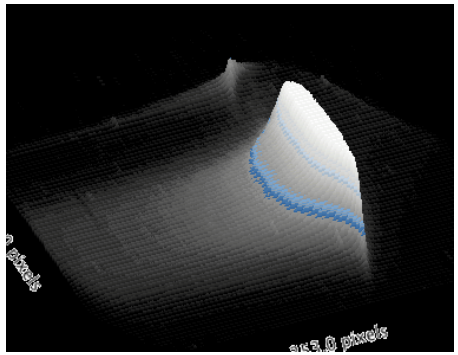
Laser generated CW e-Beam with 3 nC @ 5 kHz

2 MeV in pulse mode

25 MV/m at photocathode







Milestones reported to DoE NP Q3 FY15

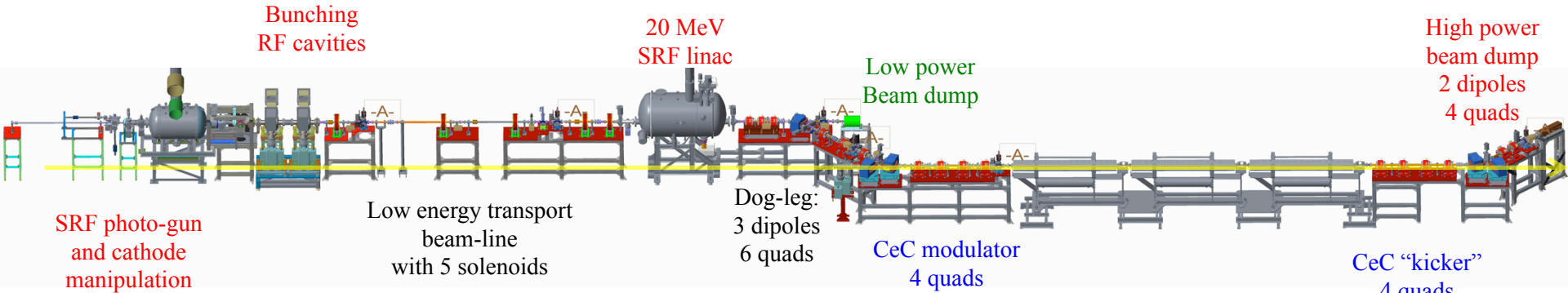
Demonstrating operation of 112 MHz SRF gun with 3 nC charge per bunch, 1.6 to 1.7 MeV kinetic energy in CW mode and above 2 MeV in pulsed mode.

Production of high QE photocathodes for 112 MHz SRF gun.

Receiving helical wiggler system for CeC PoP FEL amplifier

Completion of the 704 MHz SRF linac cryo-module at Niowave Inc.

Completing the low energy transport beam line and its control system.


Bunching
RF cavities
20 MeV
SRF linac
Low power
Beam dump
High power
beam dump
2 dipoles
4 quads
SRF photo-gun
and cathode
manipulation
system
Low energy transport
beam-line
with 5 solenoids
Dog-leg:
3 dipoles
6 quads
CeC modulator
4 quads
CeC “kicker”
4 quads

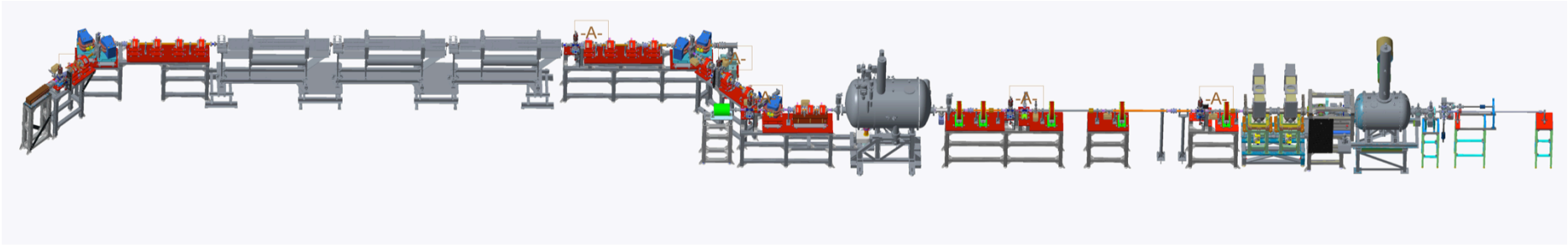


Table of matching energies

Electron Beam, MeV	Ion beam, GeV
10	18.5
15	27.8
20	37
21.95	**40**
25	46.3